1985

Canopy architecture of a red maple edge stand measured by a point drop method

D.R. Miller

J.D. Lin

CANOPY ARCHITECTURE OF A RED MAPLE EDGE STAND MEASURED BY A POINT DROP METHOD

D. R. Miller and J. D. Lin

University of Connecticut

ABSTRACT

The three-dimensional spatial distribution of leaf areas, leaf angles and leaf azimuths were measured in the experimental stand. Point drops were used to indicate sample leaves. Inclination and azimuth angles were measured by hand. The effect of the forest edge on the canopy architecture extends about one tree height into the stand. The leaf density is twice as large at the edge as in the interior of the stand due to a vertical side at the edge. The leaves in the upper crown and those exposed at the edge are inclined from the horizontal over a wide range of angles. Shade leaves are essentially horizontal. Those exposed to solar radiation at the edge are inclined and oriented with their dorsal surface facing the edge.

INTRODUCTION

Extensive attempts to model the heat and mass transfer processes associated with forests have stimulated interest in the relations among crown geometry, canopy structure, aerodynamic roughness and drag. Our current attempt to define the wind field through a forest edge (Li, Lin and Miller, 1983) has pointed out the need for a better quantitative description of the three-dimensional canopy structure. This paper describes the general structure of a red maple (Acer rubrum L) edge stand which is being instrumented for extensive turbulent flow measurements and modeling studies.

B. A. Hutchison and B. B. Hicks (eds.), The Forest-Atmosphere Interaction, 59–70.

The forest stand is located on the University of Connecticut experimental farm in Coventry, CT (Lat 41° 47' 30" N, Long 72° 22' 29" W). The experimental site is a flat wetland with a 30-year old red maple (Acer rubrum L.) overstory and with occasional white pine (Pinus strobus L.) and trembling aspen (Populus tremuloides Michx.) trees at the edges. The understory vegetation is primarily blueberry (Vaccinium corymbosum L.). The stand averages 14 m tall and is adjacent to an open field of tall grass and corn. The edge between the field and the forest is straight, abrupt and oriented along a line from southwest to northeast. Thus, winds from the northwest, which prevail in this area during much of the year, are perpendicular to the edge, blowing into the forest. The experimental plot within the stand is a square area, 28 by 28 m, with one margin at the forest edge (Figure 1).

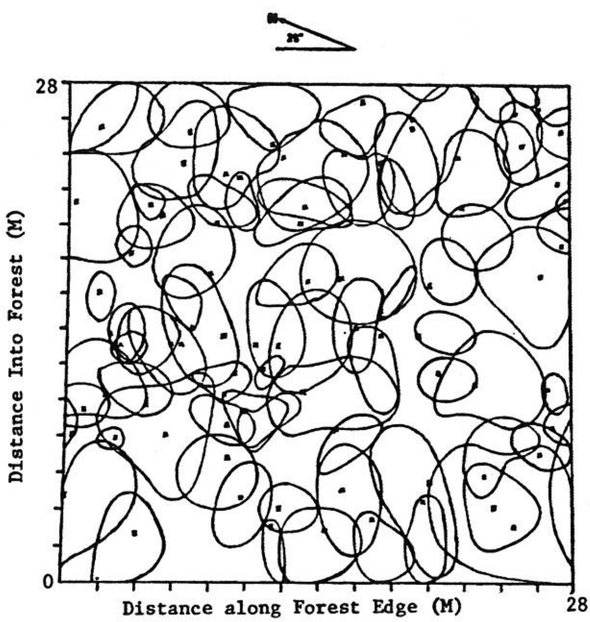

Figure 1. Tree crown projection map of experimental plot (X denotes tree stem location)

METHODS

A 100 percent inventory of tree DBH, total height, live crown length and location on a two-dimensional grid was made in the summer of 1983. Heights were measured with a hand altimeter and the trees were located with a staff compass and surveyor's chain. The horizontal extent of tree crowns was determined along transects spaced 1.5 m across the plot. The points where the crown edges intersected the transects were recorded. Leaf area distributions were sampled at the nodes of the two-meter grid throughout the plot by point drops similar to the method of Fisher and Hibbs (1982). At each sample point, a plumb-weighted line was dropped from above the canopy to the ground (Figure 2). Each leaf touched by the line was considered a sample leaf. Its height above ground, inclination angle (θ) and the azimuth angle (ϕ) of the normal to its upper surface were measured by hand with a protractor and magnetic compass. A movable hydraulic personnel lift was used to reach the sample leaves. Also recorded at each "drop" was the canopy height (h) at which the line entered the top of the crown. There were a total of 196 sample (drop) points.

Horizontal crown outlines were interpolated between the tree crown edge points and plotted to derive the tree crown projection map (Figure 1). Leaf areas at the drop points were calculated by summing the number of leaves touched by the drop line in a vertical segment. Before summing, each leaf touched was weighted by its inclination angle, measured from the horizontal,

$$LAI = \sum_{i}^{N} (1/\cos \theta_i); \ \theta < 90$$

Where:

- LAI = Leaf Area Index at the drop point.
- N = Number of leaves touched by the line in its vertical drop path.
- θ_i = Inclination angle of the individual leaf.

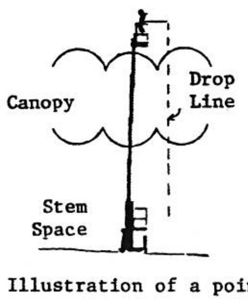

Figure 2. Illustration of a point drop sample.

RESULTS

The tree crown projection map (Figure 1) shows 15.9 percent of the ground not covered by the overstory canopy, 19.8 percent of the ground area is covered by two overlapping tree crowns and 4.7 percent is overlapped by three trees.

Figure 3 is a plot of the height (h) of the tree canopy. It shows the extreme roughness of the top surface with an almost vertical side at the irregular edge. The spatial distribution of LAI is shown in Figure 4. Figures 4 and 1 indicate that the highest leaf area densities are not closely correlated with the size of crowns or overlapping. However, Figures 3 and 4 suggest that the leaf area densities are correlated with tree heights. Simple correlations given in Table 1 bear this out.

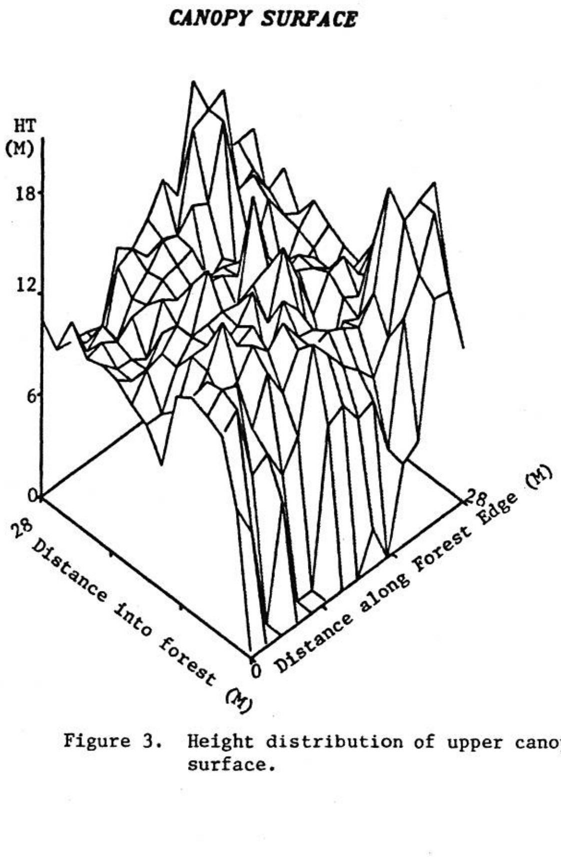

Figure 3. Height distribution of upper canopy surface.

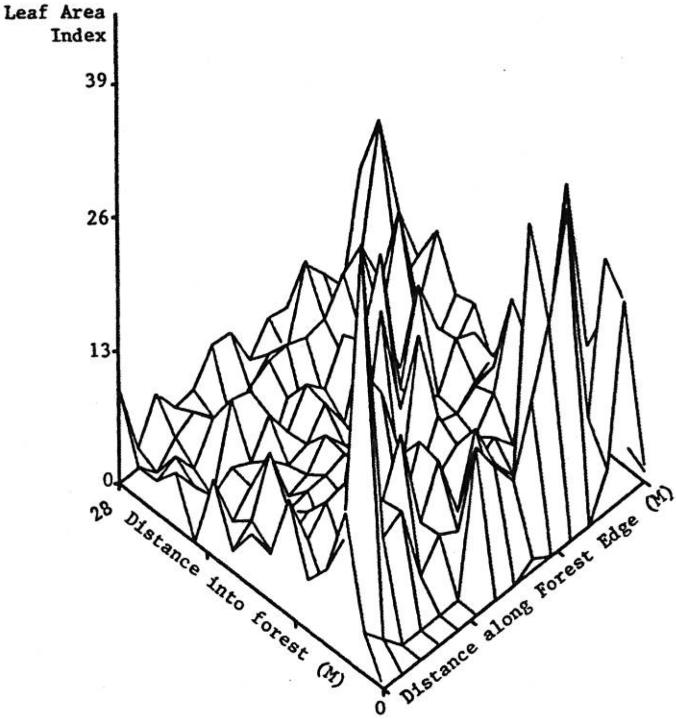

Figure 4. Spatial distribution of leaf area index.

Table 1. Matrix of correlation coefficients between Leaf Area Index (LAI), Tree Bole Diameter (DBH), Canopy Height (h), Crown Overlap (CO), and distance from the Forest Edge (x)

	LAI	DBH	h	CO	x
LAI	1	-0.01	0.89	0.65	-0.33
DBH		1	0.13	-0.06	0.15
h			1	0.47	-0.18
CO				1	-0.01
x					1

Figure 5 shows LAI as a function of distance from the edge. Each point is an average of 14 drop measurements in a line parallel to the edge. The vertical bars are the standard deviations for each average value. The LAI ranges from a high of 11.6 at the edge to about five in the stand interior. Coefficients of variation for this data set demonstrate that the relative lateral, parallel to edge, variability is higher with higher leaf density since the C. V. varied from about eight percent in the stand interior to about 15 percent near the edge. The additional foliage mass at the forest edge is primarily due to the large leaf areas below the crown level which characterize a thick crown layer near the edge. Table 2 shows leaf area at various levels in the canopy with distance into the stand from the edge. Despite the high variability as indicated in the tabulated values at all levels in the canopy, the averages remain quite uniform throughout. The major crown mass is concentrated between 9 and 12 meters and Table 2 demonstrates a spatial periodicity of about six meters between similar features of high and low leaf densities at this height. Below the canopy, the data doesn't indicate obvious periodic spatial relationships, except for decreasing leaf densities with distance from the edge. The average leaf area densities all show a leveling off at some 15 meters into the stand, indicating that the edge effect on canopy architecture extend about one tree height into the stand.

The leaf inclination angle distributions show that the sun leaves, those in the top of the canopy above 15 meters, have a wide distribution of inclination angles; whereas the shade leaves are essentially within 15 degrees of horizontal. Probability distributions of leaf inclination angles are shown in Figure 6. The data was grouped into understory-layers (0-5 m), the lower canopy layer (5-10 m), the mid-canopy layer (10-15 m), and the upper canopy layer (15-20 m). In the upper canopy the probability of encountering any given leaf angle between 15 and 75 degrees is approximately two-tenths. The two lowest layers (primarily shade leaves) have the large majority of leaves almost horizontal (probability ≈ .7). The leaf inclinations in the midcrown layer are midway between the primarily exposed and primarily shaded layers as would be expected.

Figure 6 is somewhat misleading because the edge trees are included and the leaves exposed at the lower edge have an angle distribution similar to those at the top of the canopy thus a wider spectrum of angles appears in the understory than would be the case if no edge were present.

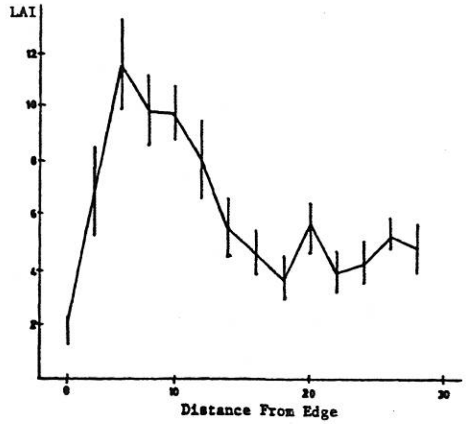

Figure 5. Leaf Area Index as a function of distance from the edge. Vertical bars are standard deviations.

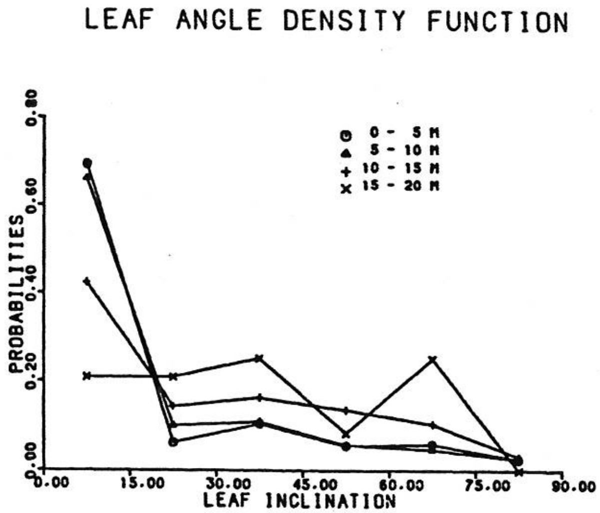

Figure 6. Leaf inclination angle distributions in four canopy layers.

Table 2. Lateral averages (LAI) and variances (s^2) of Leaf Area Index for one meter height intervals.

Distance from edge (m)	Height above ground (m) 0 - 1		1 - 2		2 - 3		3 - 4		4 - 5	
	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2
0 - 2	.00	.00	.00	.00	.08	.09	.39	1.06	.15	.15
2 - 4	.26	.61	.13	.27	.42	.70	1.40	10.26	.96	4.76
4 - 6	.22	.35	.44	1.23	.07	.07	.54	1.61	.42	.39
6 - 8	.54	3.33	.14	.15	.29	.43	.08	.09	.68	2.65
8 - 12	.37	.42	.00	.00	.29	.41	.00	.00	.33	.79
12 - 14	.16	.17	.40	1.18	.34	.39	.14	.13	.27	.22
14 - 16	.13	.27	.00	.00	.00	.00	.00	.00	.14	.14
16 - 18	.27	.62	.48	3.41	.00	.00	.00	.00	.07	.07
18 - 20	.10	.17	.00	.00	.29	.26	.07	.07	.10	.16
20 - 22	.08	.09	.22	.42	.00	.00	.14	.13	.69	3.76
22 - 24	.00	.00	.13	.13	.07	.07	.20	.17	.07	.07
24 - 26	.00	.00	.07	.07	.16	.18	.07	.07	.13	.13
26 - 28	.07	.07	.00	.00	.00	.00	.00	.00	.07	.07
28 - 30	.07	.07	.00	.00	.13	.13	.00	.00	.08	.08
30 - 32	.00	.00	.07	.07	.07	.07	.07	.07	.07	.07

Table 2. Continued

Distance from edge (m)	Height above ground (m) 5 - 6		6 - 7		7 - 8		8 - 9		9 - 10	
	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2
0 - 2	.00	.00	.51	4.01	.14	.30	.00	.00	.07	.07
2 - 4	.59	2.39	.16	.19	1.19	5.82	.73	3.14	.45	3.06
4 - 6	.98	2.71	.89	1.44	.89	1.82	2.44	21.30	.97	1.88
6 - 8	.40	.55	.43	.48	.55	.88	.36	.45	1.19	1.03
8 - 12	.51	1.39	.78	4.93	.39	1.07	.87	2.69	.65	.98
12 - 14	.20	.17	.56	.76	.32	.58	.29	.41	1.24	2.39
14 - 16	.16	.41	.20	.17	.49	.64	.46	.64	.71	1.11
16 - 18	.27	.35	.14	.14	.25	.28	.21	.34	.61	.87
18 - 20	.08	.09	.20	.33	.00	.00	.34	.54	.34	.40
20 - 22	.14	.13	.27	.36	.34	.56	.57	.46	1.55	2.74
22 - 24	.00	.00	.28	.36	.27	.37	.67	.83	.85	1.06
24 - 26	.09	.13	.24	.26	.92	1.29	.40	.69	.81	1.58
26 - 28	.14	.13	.21	.19	.47	.42	.69	1.33	.76	1.20
28 - 30	.78	2.9	.72	2.31	.75	4.38	.65	.76	.62	1.07
30 - 32	.20	.18	.48	.68	.84	1.41	.34	.41	.88	1.59

Table 2. Continued

Distance from edge (m)	Height above ground (m) 10 - 11		11 - 12		12 - 13		13 - 14		>14	
	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2	$\overline{LAI}$	s^2
0 - 2	.07	.07	.14	.29	.27	1.13	.07	.07	.00	.00
2 - 4	1.00	6.98	.72	3.40	.07	.07	.19	.57	.00	.00
4 - 6	.71	.99	1.33	5.03	.91	3.58	.20	.17	.75	1.17
6 - 8	2.05	8.11	1.76	7.65	.75	1.25	.07	.07	1.01	1.29
8 - 12	.50	.81	.77	1.67	.07	.07	.21	.35	.00	.00
12 - 14	1.39	3.96	.97	3.02	1.82	19.11	.00	.00	.00	.00
14 - 16	.69	2.81	1.95	7.22	.40	.86	.19	.56	.00	.00
16 - 18	.50	.46	1.15	2.07	.69	1.11	.00	.00	.00	.00
18 - 20	1.32	2.99	.27	.64	.18	.49	.09	.13	.32	.82
20 - 22	1.32	2.33	.40	.81	.08	.09	.00	.00	.00	.00
22 - 24	1.14	2.67	.24	.87	.00	.00	.00	.00	.00	.00
24 - 26	.59	1.57	.77	6.09	.00	.00	.00	.00	.00	.00
26 - 28	1.18	1.91	.78	.84	.53	.81	.07	.07	.75	1.2
28 - 30	.40	.61	.00	.00	.00	.00	.00	.00	.49	1.90
30 - 32	.76	2.21	.71	.88	.52	.76	.07	.07	.37	1.28

Azimuth angle distribution in the stand are shown in figure 7. The sun leaves which dominate the top layer are oriented generally south-east. Whereas the understory leaves at the edge are generally facing west-north-west.

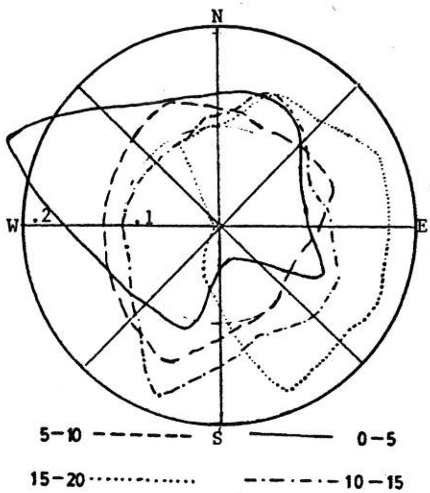

Figure 7. Azimuth angle (measured from North) distributions of leaves in four canopy layers.

CONCLUSION

The point drop method used in this project is an efficient non-destructive sampling technique to quantify the spatial distributions of foliage in forest stands. The effect of the forest edge on canopy architecture, leaf densities, orientations, and angles extends about one tree height into a 14 meter tall red maple stand.

REFERENCES

Fisher, J. B. and D. E. Hibbs: 1982. Plasticity of tree architecture: specific and ecological variation found in Aubreauille's model. Am. J. Bot. 69: 690-702.

Li, Z. J., J. D. Lin and D. R. Miller: 1983. A numerical model of airflow through and over a forest canopy. Preprints AMS Seventh Conference on Fire and Forest Meteorology, Fort Collins, Colorado. pp. 123-125.